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THE EFFECT OF SOLUTION ANNEALING ON PROPERTIES OF STEEL NITRONIC 60

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Preliminary Note – Prethodno priopćenje

Nitronic 60 (UNS S21800) is a highly alloyed austenitic stainless steel. This steel provides exceptional wear and galling resistance as well as a high temperature corrosion resistance. Increasing strength of Nitronic 60 is obtained by cold deformation. A solution annealing is necessary to achieve a complete austenitic microstructure without the presence of precipitates in the matrix. This paper describes determination of the appropriate heat treatment to obtain austenitic microstructure with a minimum consumption of time and energy.

Key words: Nitronic 60, austenite, solution annealing, hardness, delta ferrite

Uticaj otapajućeg žarenja na svojstva čelika Nitronic 60. Nitronic 60 (UNS S21800) je visoko legirani austenitni nehrđajući čelik. Izraženo svojstvo ovog materijala je otpornost na habanje i trganje površine kao i otpornost prema visokotemperaturnoj koroziji. Najčešći postupak očvršćavanja čelika je deformacijsko, postupkom hladne deformacije. Da bi se postigla potpuna austenitna mikrostruktura bez prisustva precipitata u matriksu potrebno je izvršiti tzv. otapajuće žarenje. U ovom radu je opisan postupak određivanja odgovarajućeg toplinskog tretmana da bi se dobila odgovarajuća mikrostruktura uz minimalan utrošak vremena i energije.

Ključne riječi: Nitronic 60, austenit, otapajuće žarenje, tvrdoća, delta ferit

INTRODUCTION

Austenitic stainless steels have the widest application in the industry. According to the literature, the production of austenitic stainless steels belong to more than 2/3 of the total world production of stainless steel [1]. These steels have a good mechanical and corrosion properties at high temperatures and loads and provide exceptional wear and galling resistance as well as a high temperature corrosion resistance [2,3]. Nitronic 60 is a commercial name for a highly alloyed austenitic steel was developed specifically for antigalling service. In comparison to other austenitic steel this steel has good to excellent galling resistance [4-6]. One of the projects of the Institute „Kemal Kapetanović“ in Zenica is to define the technology of production of steel Nitronic 60. The technology for the production of steel is protected by the manufacturer. Accordingly, a number of research activities have needed to make to define the technology of production this steel in semi-industrial conditions of the Institute [7,8,9]. One of the activities was to define the program of solution annealing and its influence on the mechanical properties especially on the hardness.

The aim of the solution annealing is to get an austenite microstructure with disolved carbides in matrix by the heat treating of steel in the temperature interval from 1000 to 1150 °C and by quenching in the water [10]. Since, the solution annealing technology is not defined for this type of steel, the experiment was done for different temperature and times of the heat treatment. Also, purpose of experiment was to define technology that would give the desired microstructure and properties with a minimum consumption of time and energy.

EXPERIMENTAL WORK

Melts tested in this work were prepared in vacuum induction furnace. The samples are taken from the steel bar Ø 16 mm and tested at 950, 1020 and 1100 °C for different periods of times 1, 2 and 3 hours. The chemical composition (Table 1) for three melts are in accordance with the standard while the chemical composition of the fourth melt exceeds the prescribed values. The chemical composition of steel Nitronic 60 is not standardized, the chemical composition of UNS S21800 steel can be used as a substitute for this steel.

The aim of this investigation was to determine the influence of chemical composition on the properties of the materials. Special attention is given to the influence of delta ferrite, whose appearance is related to the chemical composition of steel, Table 2. The delta ferrite content is determined in accordance with the modified Schaeffler-DeLong's diagram [2] and by using the Olympus software for the microstructure phase analysis (Olympus analysis Materials Science, Digital Imaging Solu-

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Table 1 **The chemical composition of Nitronic 60 steel / wt%**

Melt	Chemical composition							
	C	Si	Mn	Cr	Ni	P	S	N
Prescribed	0,1 (max)	3,5-4,5	7,0-9,0	16,0-18,0	8,0-9,0	0,040 (max)	0,040 (max)	0,08-0,18
V1692	0,04	4,41	7,4	18,0	8,1	0,007	0,005	0,183
V1696	0,05	3,5	7,9	16,9	8,6	0,005	0,005	0,120
V1699	0,04	4,95	7,5	19,5	8,5	0,005	0,008	0,129
V1702	0,04	3,8	7,4	17,3	8,6	0,007	0,011	0,158

Table 2 **The content of delta ferrite / %**

Melt	Accordance with Schaeffler-Delong diagram	Accordance with metallographic analysis
V1696	cca 3	cca 2,6
V1702	cca 4	cca 4,75
V1692	cca 7,6	cca 8,86
V1699	>13,8	cca 17,04

tions). Chromium (Cr) and silicon (Si) are the chemical elements that initiate the formation of delta ferrite and because of that the behavior of melt V1699 was observed. For this melt, the content of these elements exceeds the prescribed values.

ANALYSIS OF THE RESULTS

Metallographic analysis

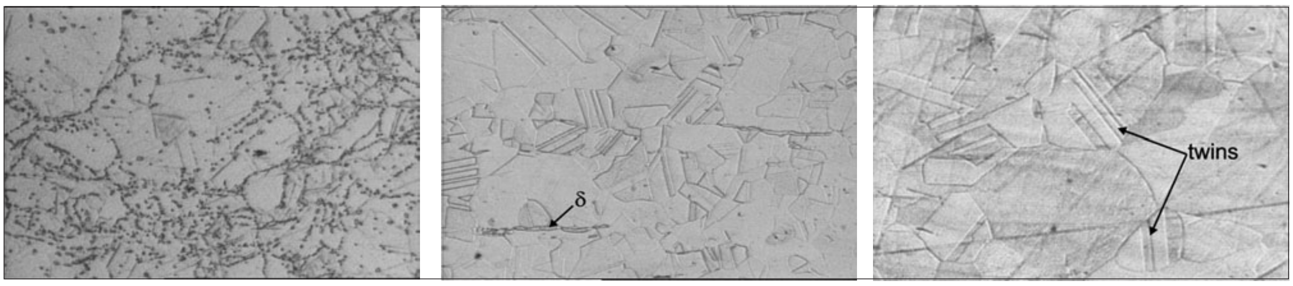
The heat treated samples were analyzed by optical microscope after etching by aqua regia. The samples treated at 950 °C show austenite microstructure with delta ferrite and precipitates. The precipitates are present inside the grain and at grain boundaries, Figure 1. All samples treated at 1020 i 1100 °C for 1, 2 and 3 hours show austenite microstructure with twins and delta ferrite.

The content of the delta ferrite is different for different melts, Figure 2.

Hardness Testing

To examine the influence of the heat treatment temperature and time on the mechanical properties of the steel, the hardness tests were performed according to standard EN ISO 6 508-1 / 2007 BAS and BAS EN ISO 6 507-1 / 2007, [11,12]. Two methods were used for hardness testing Rockwell (HRC) and Vickers (HV). All results are converted into the method by Brinell (HB) in accordance with ASTM E140-97 [13] to be compared with the prescribed standard for this steel. The results are present as follows:

– the hardness values for all tested melts are in the range from 170 to 290 HB (max. value for steel Nitronic 60 is 241HB according to Standard ASTM A276, [14])



a) b) c)

Figure 1 Microstructure analysis for melt V1696 a) 950 °C/60 minutes/water, b) 1020 °C/60 minutes/water and c) 1100 °C/60 minutes/water (100 x, aqua regia)

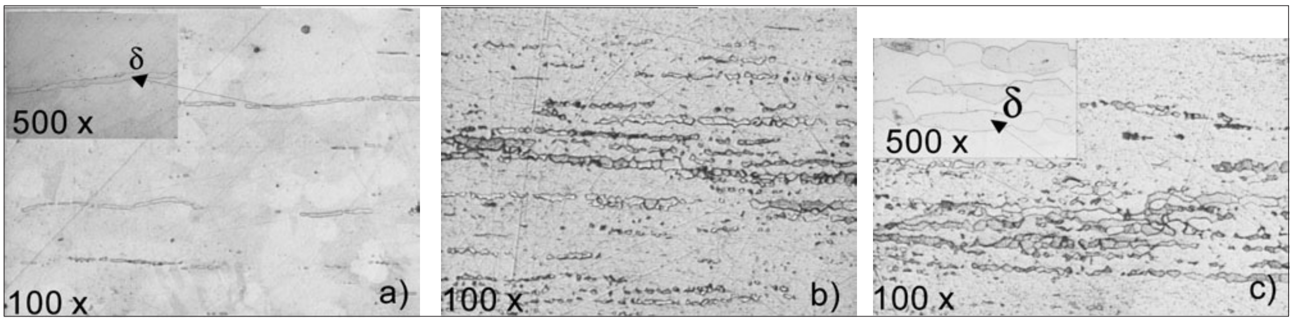


Figure 2 The content of delta ferrite for different melts: a) V1696, b) V1692 and c) V1699 (aqua regia)

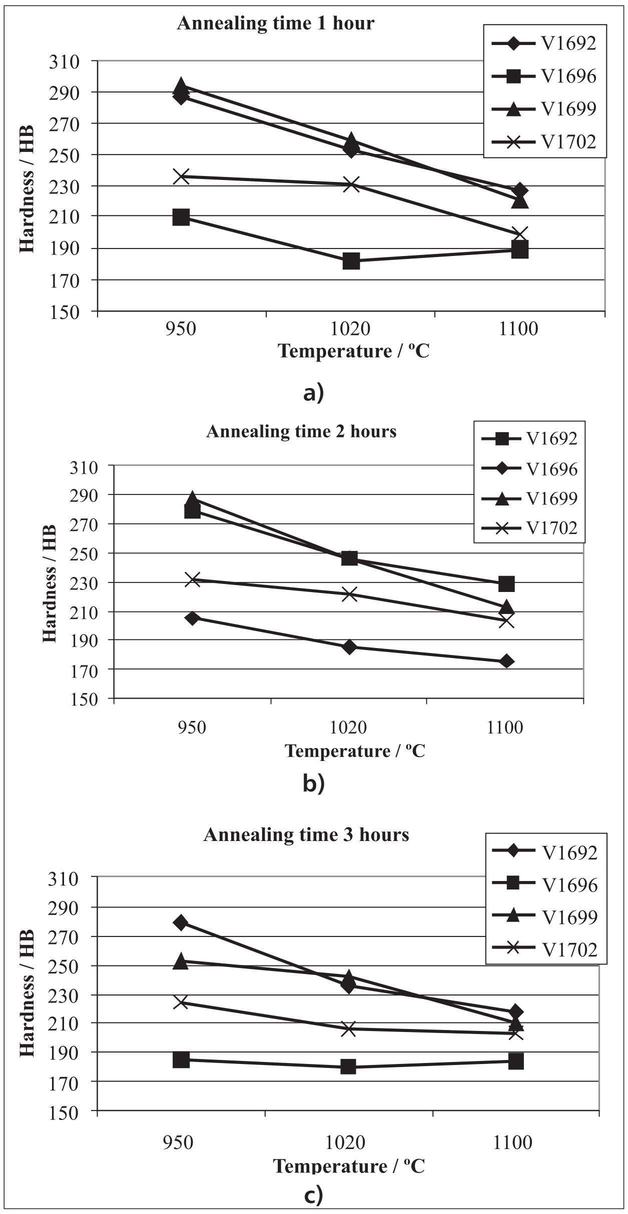


Figure 3 The hardness values in relation to the annealing temperature

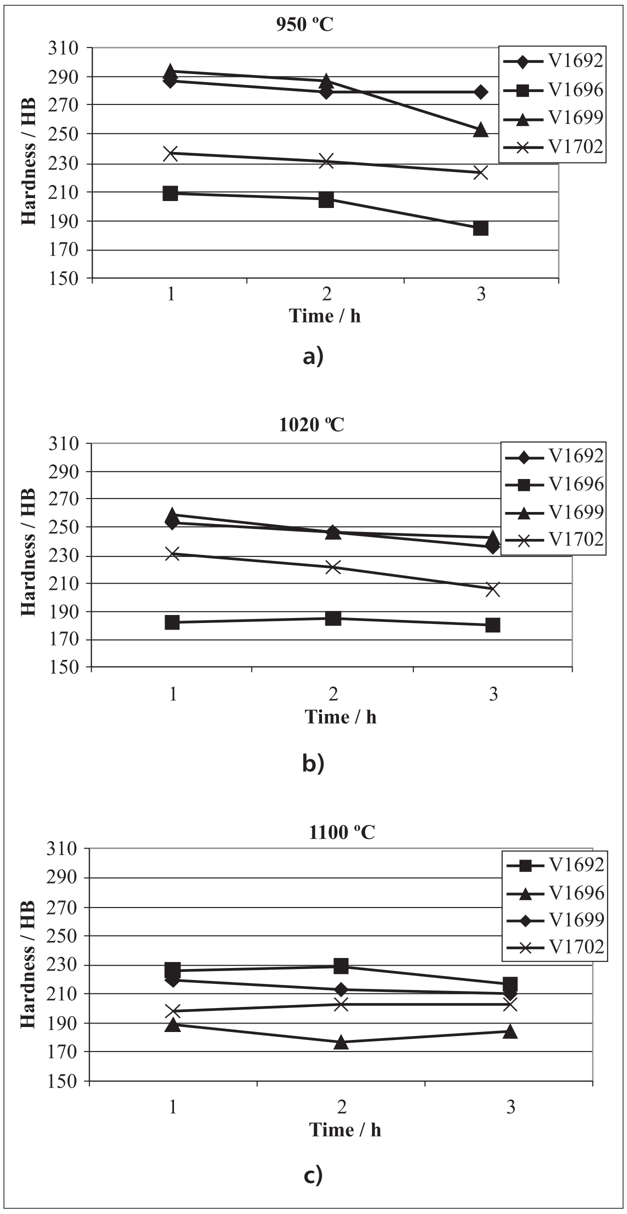


Figure 4 The hardness values in relation to time for different annealing temperatures

- the hardness is decreased by increasing temperature, Figure 3
- the samples treated at 950 °C have max. hardness
- the hardness decreased by increasing of treatmen time on the constant temperature, Figure 4
- the hardness is increased by increasing delta ferrite content
- for two melts (V1692 and V1699) whose percentage of delta ferrite (calculated according to the modified Schaeffler's diagram) is about 8 % and 13,8 %, the hardness values are similar.

CONCLUSIONS

After data analysis following can be concluded:

- the heat tretament which consists of heating the steel in the temperature interval from 1020 to 1100 °C for a period of 1, 2 and 3 hours, followed by quenching in the water will ensure an austenite microstructure with twins, which are typical for this microstructure,
- the heat treatmen at 950 °C will not ensure fully austenite microstructure, the precipitates will stay undissolved,
- the metalographic analysis showed presence of delta ferrite in the matrix,
- the chemical composition influences the content of delta ferrite. The melts with increased content of chromium and silicon have higher percent of delta ferrite in matrix,
- the melts with higher content of delta ferrite have higher hardness,
- to save energy and time as the optimal heat treatment for further work is recommended heating at 1020 °C for 1 hour followed by quenching in the water.

The conclusions based on the analysis of results will be used in defining of experiment to predict the effect of ferrite- and austenite stabilisers elements on formation of delta ferrite and its influence on the mechanical properties of Nitronic 60 steel.

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